Chapter-6: OSPF and Integrated IS-IS

Deep Medhi and Karthik Ramasamy

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Link State Protocol: a quick review

- Link information (such as "link cost") is accomplished through flooding: Link state advertisement (LSA) is generating by the originating node (router)
- Because flooding, a node may find out about a link's cost from two different neighbors
  - Need to address how to find out who is providing the most recent information
  - Accomplished through sequence number field
  - Also, age field is added for safeguard

Going from theory to practice

- Consider a LAN where N routers are located
  - In the basic link state framework, this would mean that all routers are logically connected to every other router
    - Leads to N(N-1)/2 links
    - However, all links are the 'same'!
    - Unnecessary extra work – communication overhead, routing computation overhead
    - Better to summarize
  - Means, all links aren't the same!
    - Define different link types
- In a large network, the topology has certain hierarchy
  - Need to address manageability and scalability
- In an IP network, how to accomplish flooding
  - Is there a way to take advantage of addressing
  - Do we need reliable delivery?
- … many issues!

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OSPF protocol features

- Network Hierarchy
- Router Classification
- Network Type
- Flooding
- Link State Advertisement
- …

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OSPF: Network Hierarchy

- The protocol provides the functionality to divide a network into subdomains, commonly referred to as areas
  - Must have a core area: backbone area
    - Identified with Area ID 0 (in 32-bit, it's 0.0.0.0)
  - Other areas ("low-level areas") are sequentially numbered: Area 1 (0.0.0.1), Area 2, and so on
- A two-level hierarchy can be set up
  - Area 1, 2, and so on are all connected to backbone Area 0

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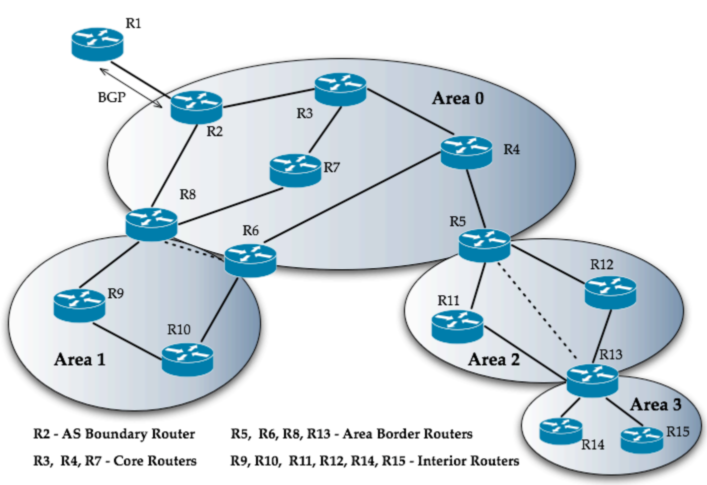
OSPF: Areas



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OSPF: Network Types

- Network here refers to the underlying property and how it might be beneficial to encode this information
  - Point-to-Point networks (a normal link)
  - Broadcast networks
    - in a LAN environment, through broadcasting
    - A router is elected as DR (Designated Router) and Backup DR (BDR)
  - Non-broadcast multiaccess (NBMA) networks
    - Mutiple routers, but no direct broadcast capability (e.g., ATM)
    - Selects also DR and BDR
  - Point-to-multipoint networks
    - Similar to non-broadcast, OSPF's mode of operations is different
  - Virtual Links
    - Connect any area with the backbone using a non-backbone (transit) area

OSPF: router classification

- Four different types:
  - Area-Border Routers:
    - Sits between backbone area and the low-level areas
  - Internal Routers:
    - Sits within a low-level area
  - Backbone Routers:
    - Routers located in Area 0
  - AS Boundary Routers:
    - Located in Area 0 with connectivity to other AS
      - Must handle multiple routing protocols

OSPF: Flooding

- IP packet header: protocol field set to 89 for LS update
- Point-to-point networks: updates use 224.0.0.5 (AllSPFRouters)
- Any OSPF packets that orginate from a DR or a BDR;
- On broadcast networks:
  - All non-DR and non-BDR orutiers send LSU using address 224.0.0.6 ("AllDRouters")
- Uses its own reliable delivery mechanism
- Retransmission – always as unicast
- Parameters:
  - LSRefreshTime (30 min)
  - MinLSInternval (5 sec): generation of any particular LSA
  - MinLSArrival

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LSA-types

- Several types; most common
  - Router LSA (1)
    - Generated for each interface
  - Network LSA (2)
    - Applicable to multiaccess network, generatged by the DR
  - Network Summary LSA (3)
    - Area Border routers generate Network Summary LSA (for outside the area)
  - AS Border Router Summary LSA (4)
    - Advertise externally to an area about Border routers
  - AS External LSA (5)
    - Generated by AS border router for external LSA
- There are six additional LSA types

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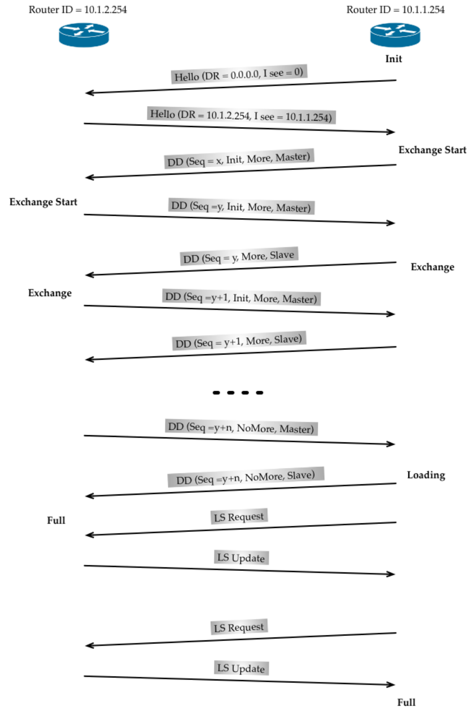
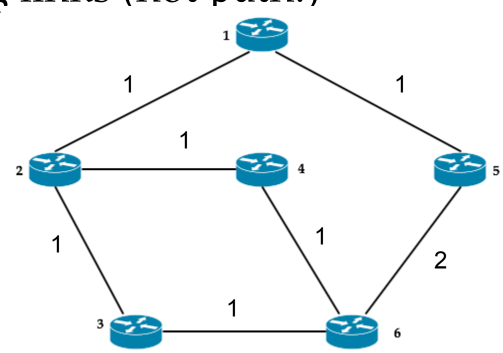
Subprotocols

- Hello
- Database Synchronization



Equal Cost multi-path (ECMP)

- Consider from 1 to 6; It's 'equal' in outgoing links (not path!)



From 1 to 6:
Path 1-2-3-4: 25%, Path 1-2-4-6: 25%; Path 1-5-6: 50% (so NOT based on path)

ECMP implementation

- Equal is not based on per packet basis
  - Would impact TCP performance if two paths have different delays etc
- Allocation on choosing is per TCP flow basis
- Implementation at software level need to add randomization; otherwise, it'll always take the same path (why?)

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OSPF: Additional features

- Stub Areas
  - An area where information about external routers is not sent
- Not-so-stubby area (NSSA)

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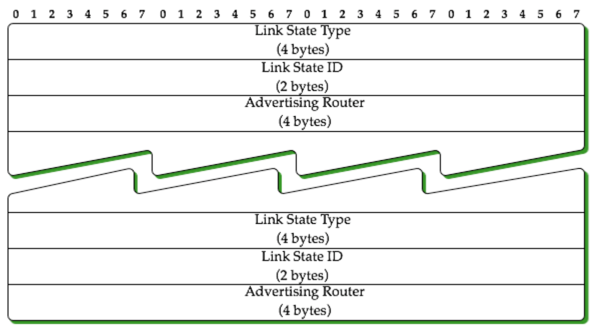
OSPF link state request packet



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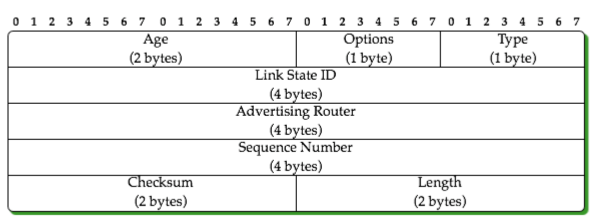
LSA header



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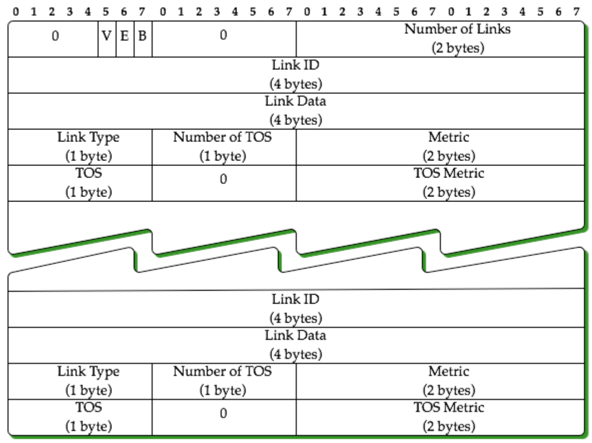
OPSF Router LSA (type=1)

- V/E/B use dor Virtual, AS boundary, area border



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Router LSA: Link Type, Link ID, and Link Data

TABLE 6.1 Router LSA: Link Type, Link ID, and Link Data.

LinkType	Description	Link ID	Link Data
1	Point-to-point link	Neighboring router's Router ID	Interface IP address of originating router
2	Link to transit network	Interface IP address of Designated Router	Interface IP address of originating router
3	Link to stub network	IP network or subnet address	Network's IP address
4	Virtual link	Neighboring router's Router ID	Interface IP address

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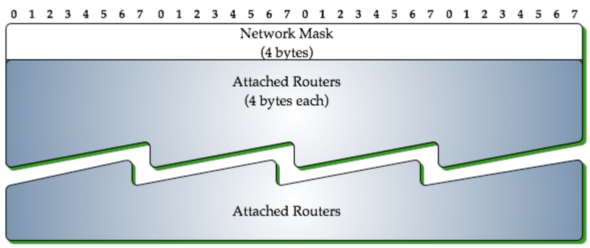
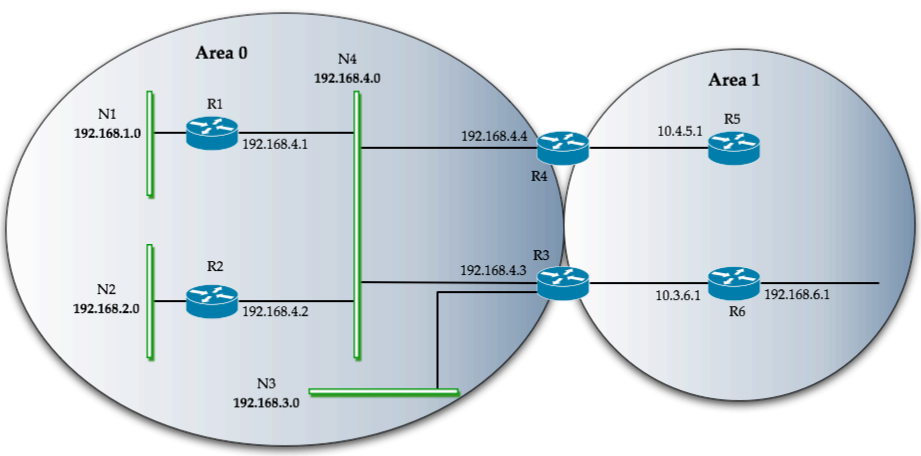
OSPF Network LSA (type=2)



- Attached router is repeated onece fore each router this is fully adjacent to the DR

Example



```
// Router LSA of R3 for Area 1
LS age = 0                          //always true on origination
Options = (E-bit)
LS type = 1                         //indicates Router LSA
Link State ID = 192.168.4.3         //R3's Router ID
Advertising Router = 192.168.4.3    //R3's Router ID
bit E = 0                           //not an AS boundary router
bit B = 1                           //area border router
#links = 2
   Link ID = 192.168.4.4            //IP address of Designated Router
   Link Data = 192.168.4.3          //R3's IP interface to net
   Type = 2                         //connects to transit network
   # TOS metrics = 0
   metric = 1                       // End of first Link ID info
   Link ID = 192.168.3.0            //IP Network number
   Link Data = 255.255.255.0        //Network mask
   Type = 3                         //connects to stub network
   # TOS metrics = 0
   metric = 1                       // End of Second Link ID info
```

FIGURE 6.14 Router LSA of R3 in Area 1 for the network example in Figure 6.13.

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```
// Network LSA for Network N4
LS age = 0                          //always true on origination
Options = (E-bit)
LS type = 2                         //indicates Network LSA
Link State ID = 192.168.4.4         //IP address of Designated Router
Advertising Router = 192.168.4.4    //R4's Router ID
Network Mask = 255.255.255.0
   Attached Router = 192.168.4.4    //Router ID
   Attached Router = 192.168.4.1    //Router ID
   Attached Router = 192.168.4.2    //Router ID
   Attached Router = 192.168.4.3    //Router ID
```

FIGURE 6.15 Network LSA for Network N4 for the network example in Figure 6.13.

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```
// R3's Router LSA for Area 0
LS age = 0                         //always true on origination
Options = (E-bit)
LS type = 1                        //indicates Router LSA
Link State ID = 192.168.4.3        //R3's router ID
Advertising Router = 192.168.4.3   //R3's router ID
bit E = 0                          //not an AS boundary router
bit B = 1                          //area border router
#links = 1
  Link ID = 192.168.6.1            //Neighbor's Router ID
  Link Data = 10.3.6.1             //MIB-II ifIndex of P-P link
  Type = 1                         //connects to router
  # TOS metrics = 0
  metric = 1
```

FIGURE 6.16 Router LSA for R3 in Area 0 for the network example in Figure 6.13.

Integrated IS-IS

- Originally defined for OSI CLNP as IS-IS
- Integrated IS-IS means its ‘customized’ for IP networks

- Areas: two-level hierarchy, routers in backbone are called L2 routers; otherwise, L1 routers
- OSI-NSAP addressing
- Link metric range
  - Originally, 0-63 (“narrow”)
  - Extended, 0 to 2^24-1 (“wide”)
- TLV encoding

IS-IS address field set up for IP addressing

Field	Size	Value
AFI (Authority and Format Identifier)	1 byte	“47”
ICD (International Code Designator)	2 bytes	“00 05”
DFI (Domain-Specific Path Format Identifier)	1 byte	“xx”
AAI (Administrative Authority Identifier)	3 bytes	“xx xx xx”
Reserved	2 bytes	Must be “00 00”
RDI (Routing Domain identifier)	2 bytes	Contains autonomous system number
Area	2 bytes	Assigned by the authorities responsible for the routing domain to uniquely identify areas
System ID	6 bytes	Use either (1) “02 00” prepended to the 4-byte IP address of the router, or (2) IEEE 802 48-bit MAC address
N-Selector (upper layer identifier)	1 byte	Set to zero

TABLE 6.3 IS-IS and OSPF development/deployment timeline (adapted from [354]).

Year	Note
1987	IS-IS (CLNP) chosen as the OSI intradomain protocol from DECnet proposal
1988	NSFnet deployed; routing protocol uses an early draft of IS-IS
	Work on OSPF started
	IP extensions to IS-IS defined
1989	OSPFv1 (RFC 1131) published
	Proteon ships OSPF implementation
	IS-IS becomes ISO proposed standard
1990	Integrated IS-IS (RFC 1195) published
1991	OSPF v2 (RFC 1247) published
	Cisco ships its OSPF implementation
	Cisco ships its OSI-only IS-IS implementation
1992	Cisco ships dual–IS-IS implementation
	Many deployment of OSPF
1993	Novell publishes NLSP
1994	Cisco ships NLSP, rewriting IS-IS as well
	IS-IS is recommended for large ISPs due to recent rewrite and OSPF field experience, and CLNP mandate by NSF
1995	ISPs begin deployment of IS-IS
1996–1998	IS-IS niche popularity continues to grow (some ISPs switch to it from OSPF)
	IS-IS becomes barrier to entry for router vendors targeting large ISPs
	Juniper and other vendors ship IS-IS–capable routers
1999–present	Extensions continue for both protocols in parallel (e.g., Traffic Engineering)

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OSPF/IS-IS extension

- Requirements for Traffic Engineering for MPLS: RFC 2702, September 1999
- OSPF TE extension: Traffic Engineering (e.g., MPLS networks)
  - RFC 3630, September 2003
  - Allows to include link-related information such as bandwidth
- IS-IS TE extension:
  - RFC 3784, June 2004 (obsolete)
  - RFC 5305, October 2008

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Multi-Topology OSPF/IS-IS

- Why?
  - To route differently in each topology
    - Separately routing table created for "each" topology
    - Can give priority for certain traffic, or, can have a topology for failure scenarios (avoids recomputing shortest paths for such failure)
- RFC 4915, June 2007